

# **GRADUATE STUDENT HANDBOOK**

## **Electrical and Computer Engineering Department**

### **Montana State University**

This handbook provides guidelines for the electrical and computer engineering graduate programs at Montana State University – Bozeman. In the event of an inconsistency, all Graduate School and Montana State University policies take precedence. Applicants and students should refer to the Graduate School webpage (<http://www.montana.edu/gradschool/>).

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# 1 ECE Graduate Program at Montana State University

## 1.1 Overview

Welcome to graduate study in the Electrical and Computer Engineering (ECE) department at Montana State University! We are a dynamic department with world-class faculty conducting nationally and internationally recognized research in exciting, interdisciplinary fields that provide superb graduate student research opportunities.

Montana State University (MSU) is in Bozeman, Montana, a vibrant small city in southwestern Montana (45.7°N, 111.0°W), approximately 145 km (90 mi) north of Yellowstone National Park, immediately adjacent to large regions of national forest and mountains. The Bozeman area provides unparalleled opportunities for outdoor recreation, while also being home to numerous optics, electronics, and software companies. Many of these have their roots in MSU graduate research programs and interact closely with our students and faculty.

The purpose of this handbook is to orient you to the available graduate degree options and to guide you through the process of obtaining a graduate degree in our department. Each student has the responsibility of working with his or her graduate advisor to ensure that all requirements are met in their degree program. The Graduate School policies prevail in the event of a conflict with the policies described here unless it is stated explicitly that we have approval for a modified requirement (MSU Graduate School policies:

<https://www.montana.edu/gradschool/policy/index.html>).

## 1.2 Degree options

The ECE department offers the following graduate degrees:

**Doctor of Philosophy:** Ph.D. in Electrical Engineering (EE Ph.D.)

**Master of Science:** M.S. in Electrical Engineering, thesis or professional paper option (MSEE)

**Master of Science:** M.S. in Optics and Photonics, thesis or professional paper option (MSOP)

**Master of Engineering:** M.Eng. in Electrical Engineering, coursework-only degree (MENG)

The **EE Ph.D.** program leads to the Ph.D. degree, which is granted in recognition of advanced accomplishment and original contribution to the field. The Ph.D. is the highest academic degree and is a research-intensive program that requires completion of sixty (60) credits of research and courses (including up to 30 credits counted from a previous master's degree). The primary Ph.D. requirement is to demonstrate an ability to conduct independent research, draw conclusions, and communicate the results effectively in written and oral form. See Chapter 2 for details of the EE Ph.D. program.

The **MSEE and MSOP** programs require 30 credits, including research experience reported in either a thesis (plan-A) or a professional paper (plan-B). The plan-A option focuses more heavily on research and plan-B on professional practice. Students in the EE Ph.D. program typically earn a plan-A or plan-B Master of Science degree en route to the Ph.D. Plan-A requires twenty (20) credits of approved courses and ten (10) credits of research reported in a thesis that is defended orally before the student's graduate committee and the public. Plan-B requires twenty-four or twenty-seven (24 or 27) credits of approved courses and three or six (3 or 6) credits of project

work reported in a professional paper that is approved by the student's advisor and presented to the committee and the public. See Chapter 3 for details of the MSEE program, and Chapter 4 for details of the MSOP program.

The **MENG** program leads to a terminal Master of Engineering degree. The program requires 30 credits of courses with no research paper or thesis. See Chapter 5 for details of the MENG program.

## 1.3 Admissions

### 1.3.1 Minimum requirements

Minimum requirements for admission to the ECE graduate programs are as follows (the majority of admitted students have credentials in excess of these minimum values):

- undergraduate degree in ECE or related field;
- cumulative grade-point average (GPA)  $\geq 3.0$  on a scale of 4.0 for M.S. admission;
- graduate GPA  $\geq 3.2$  for Ph.D. admission after previous graduate studies;
- three (3) **reference letters** from professors and others qualified to assess the applicant's academic achievements and potential for success in research and graduate studies;
- one-page **statement of purpose** explaining the applicant's research interests and describing specific research programs at Montana State University in which the applicant is interested (this is a very important component that is used to identify research opportunities);
- *Test of English as a Foreign Language (TOEFL)*  $\geq 90$   
or *International English Language Testing System (IELTS)*  $\geq 7.0$   
(for applicants from countries where the official language is other than English).

Admission to the ECE graduate program requires meeting the published thresholds for grades, but also depends heavily on other factors including reference letters, availability of a suitable graduate advisor, a match between an applicant's stated interests and ongoing research work, and the relative supply and demand of students in various areas.

NOTE that GRE test scores are *not* required for admission consideration, but for students who have taken the GRE, our score expectations are:

- Quantitative  $\geq 155$
- Verbal  $\geq 150$
- Analytical writing  $\geq 3.5$

### 1.3.2 Master's Degree en route to Ph.D.

Ph.D. students who do not have a master's degree will normally earn a master's en route (as the first step toward their Ph.D.). Depending on the preferences of the advisor and student and the scope of the master's and Ph.D. projects, the en route master's degree can be plan-A or plan-B. An advisor can allow the student to use up to the full 30 credits required for the master's degree to apply toward the Ph.D. (listed as "*master's degree credits to be considered toward the doctoral degree*" on the Program of Study form).

### 1.3.3 Converting admission status

The following procedures must be followed by students who wish to convert from one ECE graduate degree program to another graduate program in our department.

#### 1.3.3.1 *Continuing to Ph.D. from Master of Science (MSEE or MSOP)*

A student admitted to one of the Master of Science degree programs who wants to continue as a Ph.D. student must submit a written request to the ECE Graduate Student Progress Committee, describing their intended Ph.D. subject area and proposed advisor. This request must include a copy of their Master's degree transcripts, a recommendation letter from the Master's thesis advisor, and a letter from the proposed Ph.D. advisor. If a review of these materials leads to a decision to admit the student to the Ph.D. program, the committee will authorize the student to submit a *Change in Graduate Status* form (available online) to the Graduate School to officially change their status from M.S. to Ph.D. Such students must pass the ECE graduate qualifying exam at the Ph.D. level, either before or after entering Ph.D. studies.

#### 1.3.3.2 *Converting to Plan-B M.S.*

With approval of the advisor, a student can convert to a plan-B master's program from either a Plan-A M.S. or Ph.D. program. The student can count three (3) or six (6) previously completed credits of *Doctoral Thesis* (EELE 690) or *Master's Thesis* (EELE 590 or OPTI 590) in place of the required *Professional Paper/Project* (EELE 575 or OPTI 575) credits, but the paper must still be completed. In this case the student submits a new *Program of Study* that lists all coursework, the original EELE/OPTI 590 or EELE 690 credits, and one (1) additional credit of *Professional Paper* (EELE/OPTI 575) or *Independent Study* (EELE 592) that is granted upon approval of their professional paper (the purpose of this 1 credit is for the advisor to award a grade for the paper once it is complete). The new plan-B *Program of Study* must be submitted to the Graduate School along with a letter from the student's advisor explaining the substitution of 590/690 plus 575/592 in place of 575. When converting from a Ph.D. to a master's program, a student should use the *Change in Graduate Status* form to notify the Graduate School of their choice.

#### 1.3.3.3 *Converting from M. Eng. to M.S. or Ph.D.*

Students in the MENG program wishing to transfer to a Master of Science or Ph.D. program must submit a new application to the ECE graduate program.

#### 1.3.3.4 *Converting to M.Eng.*

Current M.S. and Ph.D. students may choose to transfer to the MENG program, but they are encouraged to do so only in consultation with their graduate advisor (e.g., normally they would then cease to be eligible for continuing financial support). A student who does not identify a viable research project by the end of the 2<sup>nd</sup> semester in residence will be transferred automatically to the MENG program.

### 1.3.4 Application deadlines and procedure

Applicants should apply online at <https://www.applyweb.com/msug/index.ftl>. We accept applications throughout the year, but for full consideration of admission with financial support, complete applications from domestic and international students must be received by the following priority deadlines:

Priority application deadline	for admission in
January 15	Fall
September 15	Spring

Applications for admission in a semester for which the priority deadline has passed will be considered on a space-available basis if received by the following university deadlines:

*Domestic students*  
 July 15 for fall  
 December 1 for spring  
 April 1 for summer

*International students*  
 May 15 for fall  
 October 1 for spring  
 February 1 for summer

Applicants will be evaluated for admission only after submitting a complete application and application fee. We do not estimate an applicant's probability of admission before an application is submitted (but prospective students can and should communicate with faculty members regarding the potential availability of research projects).

### 1.3.5 Undergraduate degree not in Electrical or Computer Engineering

We encourage well-qualified applicants with degrees in physics, optics, mathematics, computer science, biological or chemical engineering, or other closely related fields to apply. Many of our research programs cross traditional discipline boundaries and good students from allied fields do very well in our program. All applicants, regardless of undergraduate discipline, are expected to have completed mathematics courses including differential and integral calculus, multivariable calculus, and differential equations, and at least two semesters of calculus-based physics. Applicants with a bachelor's degree in **electrical engineering technology** must apply to the undergraduate program.

To be successful in the graduate program and for EE Ph.D. program students to pass the graduate qualifying exam, students with non-ECE undergraduate degrees typically develop proficiency in core areas of the ECE curriculum through individual study or by taking selected undergraduate courses. Such students should consult with their advisor to determine the needed background material and appropriate mechanism for learning it.

### 1.3.6 Transfer credit

A maximum of nine (9) credits of committee-approved courses from another institution can be transferred to fulfill ECE graduate program requirements if the grade is B or better and the credits have not been used to satisfy the requirements of another degree. This limit includes courses taken as an undergraduate student and reserved for graduate credit, courses taken as a graduate student in another department or at another university, and courses taken while in non-degree status. The student's supervisory committee also can approve up to 30 credits from a previously earned or en route master's degree to be counted on a Ph.D. *Program of Study* (note that this is different from transfer credits).

## 1.4 Financial Support

The majority of graduate students in our program receive financial support through teaching

assistantships, research assistantships, and/or fellowships, which provide opportunities for graduate students to participate in funded research projects and to develop and practice teaching and research skills. All applicants to the M.S. or Ph.D. programs are considered for financial support without submitting any additional application (Master of Engineering students are not eligible for financial support).

### **1.4.1 Research Assistantships (RAs)**

Research assistantships provide financial support to graduate students who work on externally funded research projects. The funding for RAs comes directly from grants obtained by faculty members through a competitive proposal process and is therefore available only for specific projects. The level of financial support provided by an RA may vary according to available funds on a specific project, but the RA generally pays a stipend, tuition, and fees.

Students are chosen by individual faculty members to receive RA support based on the project's needs and the student's interests and capabilities. The sponsoring faculty member typically serves as the advisor and supervisory committee chair for a student supported by their RA funds. Faculty members may end RA support for a student for reasons that include, but are not necessarily limited to, the grant ending, or insufficient research or academic progress by the student.

Work performed by students with RA support forms the basis of the student's thesis or dissertation. RAs are expected to follow the guidance of their advisor and to exercise independent motivation in exploring the research topic by discussing the research with other project participants, exploring relevant research literature, proposing alternate approaches to the project, carrying out modeling and simulation efforts, conducting experiments, analyzing results, drawing conclusions, and disseminating results through oral presentations and written publications. RAs may also work with other students, faculty, and staff and help guide the learning and work of undergraduate students.

RA funds are not provided as payment for hourly work, but rather as support for a student whose job it is to make satisfactory progress toward completion of their research project and the academic requirements of their graduate degree. *As a general guideline, a student should expect to work approximately half time on their research project while taking classes (typically 6-9 credits each semester) and to work full time on their research project when not taking classes (the latter also applies to summer terms when the student is offered summer RA support).* Graduate students' course loads typically lessen in later years, to a point where they register only for thesis or dissertation research credits by their final semesters. The time they spend on research should increase accordingly.

#### *1.4.1.1 Responsible Conduct of Research Training*

All Graduate Research Assistants supported by grants from the National Science Foundation and the National Institutes of Health (NIH) are legally required to complete training in the responsible conduct of research (i.e. research ethics): <http://www.montana.edu/orc/responsible-conduct.html>.

### **1.4.2 Graduate Teaching Assistantships (GTAs)**

Graduate teaching assistantships provide financial support to graduate students who work with faculty members to help teach classes, grade homework, supervise laboratory sessions, and otherwise support the overall instructional effort. Ph.D. students are particularly encouraged to spend some time during their graduate program as a GTA to obtain teaching experience. Graduate

TAs typically work half time and are provided a monthly stipend and tuition waiver during the academic year (fees often must still be paid by the student).

To qualify for GTA support, international students must pass either the *Test of English as a Foreign Language* internet-based (TOEFL IBT) with a minimum score of 90 or the *International English Language Testing System* (IELTS) with a minimum score of 7.0. GTAs normally are offered as short-term support while a student seeks a research project, finishes work on a thesis or dissertation, or gains desired teaching experience.

### **1.4.3 Graduate Fellowships**

A *fellowship* provides financial support to graduate students without a corresponding obligation for teaching or separately-funded research responsibilities. Fellowships are generally merit-based awards granted by internal or external sponsoring organizations to full-time students who are productively engaged in their graduate course of study. Many government and private organizations offer applications for fellowship support. Two prestigious examples are the U.S. National Science Foundation Graduate Research Fellowship (NSF GRFP) program and the U.S. National Defense Science and Engineering Graduate (NDSEG) Fellowship program. Students are encouraged to search for fellowship opportunities, and to contact the departmental graduate coordinator for more guidance.

## **1.5 Academic Standards and Retention**

Each student should be familiar with the Graduate School policies, which can be summarized as a requirement that the student maintain a cumulative 3.0 GPA in their graduate program and to achieve at least a 3.0 GPA each semester. For further detail, see the Graduate School policies: <https://www.montana.edu/gradschool/policy/index.html>.

Students may lose financial support if their academic or RA performance is deemed unsatisfactory by their advisor or if their TA duties are deemed unsatisfactory by the supervising faculty.

Academic misconduct by graduate students in the ECE department will be dealt with in accordance with MSU policy. The published definition of academic misconduct includes the following items of particular significance to graduate students: cheating; plagiarism; falsification; multiple submissions; unauthorized access to, manipulation of or tampering with laboratory equipment, experiments, computer programs without proper authorization; and misuse of research data in reporting results.

## 2 EE Ph.D. Program Requirements and Procedures

### 2.1 Committee

Admission to the EE Ph.D. program requires sponsorship by a faculty member who serves as the student's advisor and chair of the supervisory committee. By the end of the second semester in residence, the student must choose their supervisory committee members in consultation with their advisor and file a *Program of Study* approved by the full committee. The Ph.D. supervisory committee has overall responsibility for guiding the student toward successful completion of the degree and for examining the student at several points throughout the degree program. Each committee member participates in and judges the student's performance in the comprehensive examination and the dissertation defense and final examination.

The Ph.D. supervisory committee consists of at least four (4) members (including the chair) chosen by the student and advisor and approved by the Graduate School. The committee chair is normally the advisor, who must be a tenure-track faculty member in the ECE department at MSU-Bozeman. The other three members can be chosen from the faculty of the ECE department and allied departments related to the student's research work, but at least half the committee must be from the ECE tenure-track faculty. It is common for Ph.D. students to conduct interdisciplinary research, in which case the committee can include a representative of the collaborating department. For a committee member from outside the MSU faculty to be included on the committee, a vita and a supporting letter from the ECE Department Head must be submitted to the Graduate School.

### 2.2 Program of Study

The *Program of Study* form must be completed by the student and approved by the supervisory committee and the Graduate School by the end of the second semester in the graduate program. Failure to meet this deadline constitutes lack of progress toward the graduate degree and is grounds for probation, suspension of financial support, and possibly dismissal from the graduate program. This form lists all courses to be taken by the student for their graduate degree (except additional courses the supervisory committee requires to correct deficiencies). Ph.D. students should consider including courses in their program of study from appropriate departments outside of ECE that are relevant to their research.

A previously earned master's degree should be listed on the first page of the *Program of Study*. Up to thirty (30) credits can be used from a master's degree (with a grade of *B* or higher) with the advisor's approval. The exact number is to be decided by the advisor and supervisory committee. If the master's degree was earned elsewhere, a Ph.D student is required to complete at least 9 course credits at Montana State University (this number is unique to the ECE Department by Graduate School approval) and the supervisory committee may require more than 9 credits in situations where it is important for the student's program.

## **An EE Ph.D. program of study must include the following:**

Total  $\geq 60$  credits

- $\leq 28$  credits *Dissertation* (EELE 690), with minimum 18 credits.
- $\geq 32$  course credits that include:
  - 2 credits *Science Communication and Proposal Development* (ENGR 650), taken just before Comprehensive Examination.
  - $\geq 3$  credits of math, numerical methods, or statistics.
  - $\geq 27$  advisor-approved credits with all graded credits having earned a B or better.
  - $\leq 9$  credits at 4xx level

All credits must also meet the following conditions:

- Regardless of how many credits are applied from a previously earned master's degree, the Ph.D. program of study must include at least 9 credits of major courses taken at Montana State University (ECE-specific exception granted by Grad School).
- All Ph.D. credits no more than ten (10) years old at time of graduation (this limit does not apply to courses counted from a previously earned master's degree).
- $\leq 6$  credits *Independent Study* (EELE 592).
- $\leq 3$  credits pass/fail, excluding dissertation.
- $\leq 9$  credits challenged.
- No credits of 488, 489, 490, 492, 494, 498, or 589 are allowed.

## **2.3 Timeline**

During the second semester

Pass the qualifying examination (see section 2.4.1).

By the end of the second semester of Ph.D. enrollment

Select advisor and committee members and submit Program of Study form.

Within two years of the qualifying examination and after completing  $\sim 2/3$  of coursework

Pass the *comprehensive examination* (must be registered for  $\geq 3$  credits in exam semester).

In the graduation term

- Register for  $\geq 3$  credits.
- Submit *Application for Advanced Degree* to the Graduate School by September 20 for Fall, February 5 for Spring, or June 10 for Summer.
- Schedule *Dissertation Defense* (sufficiently early that all committee-required dissertation edits can be completed after the defense and by the Graduate School deadline, typically Dec. 1 for Fall, April 21 for Spring, and July 21 for Summer).
- Deliver completed dissertation to supervisory committee at least 2 weeks before defense.
- Pass *Dissertation Defense* and make dissertation corrections or modifications required by committee by Graduate School deadline, typically Dec. 1 for Fall, April 21 for Spring, and July 21 for summer.
- Submit electronic dissertation, *Electronic Thesis/Dissertation Approval Form* signed by all committee members, and *Thesis/Dissertation/Professional Paper Report* signed by the ECE department head, to the Graduate School by Graduate School deadlines referred to in previous bullet.

Note that several items must be completed by Graduate School deadlines that are approximately two weeks before the end of the graduation term, but there can be significant delays between completing each item. For example, it typically takes one week or longer after the dissertation defense before the dissertation can be submitted to the Graduate School; it also can take several days to obtain Graduate School approval. In other words, it is essentially impossible to meet graduation deadlines if the dissertation defense is held later than about three weeks before the end of the term.

## **2.4 EE Ph.D. Examinations**

There are three major examinations to be completed by a student in the EE Ph.D. program. The objectives and procedures for these examinations are described here.

### **2.4.1 Ph.D. Qualifying examination**

The Ph.D. Qualifying Exam is a written and oral exam taken in their second semester by students admitted for Ph.D. studies. A student may retake the exam a second time in the event of a failed first attempt.

#### *2.4.1.1 Written qualifying exam*

This is a 72-hour take-home exam with 2 questions covering basic concepts of math and electrical engineering tailored to the student's intended research area (e.g., biosystems, computer engineering, signal processing, controls, power, and optics). The purpose is to assess the student's undergraduate training in those areas most directly relevant to their proposed research area.

#### *2.4.1.2 Oral qualifying exam*

This is a 1-hour oral exam with three faculty members and the student. The student gives a 10-minute oral presentation about one research paper assigned by the faculty 1 week before the oral exam and one related paper the student finds. Following the brief presentation of the papers, their related methods and results, the faculty members will explore the student's understanding of the material, how the ideas flow in the papers, how the papers relate to each other, and the student's understanding and ability to clearly communicate the fundamental principles of the research area.

A student who does not pass the exam the first time will be offered a second opportunity to take the exam the next time it is offered. A student who does not pass the Ph.D. Qualifying examination at an acceptable level in two attempts will not be allowed to continue in the Ph.D. program, but can elect to continue as an M.S. student.

### **2.4.2 Comprehensive examination**

The comprehensive exam is a written and oral exam administered by the student's doctoral supervisory committee, with the following purposes:

- Require the student to delve deeply into the literature for their chosen research topic and prepare a written and oral presentation that outlines their problem, its significance, the history and status of research in the area, and their proposed research to address gaps in the past research.

- The comprehensive exam written document is created in the form of an early version of the student's eventual dissertation introduction; it is distributed to the committee two weeks prior to the exam.
- Test the student's understanding of their chosen research problem, and how the proposed work fits into the larger field.
- Assess the feasibility of the student's planned research project and the likelihood that it will result in publishable novel research.
- Give the student experience for what they will need to do at a successful dissertation defense.

The timing of this exam is after the student has taken at least 2/3 of their courses and when they are ready to define their dissertation project and move into the research-heavy phase of their Ph.D. program. For a student earning an en route MS degree, this exam would normally occur following their MS defense, approximately at the start of the third year in the graduate program.

The written exam is the document the student writes and submits to their committee (following advisor approval) 2 weeks prior to the exam. It should contain a thorough literature review, an outline of completed preliminary work, and a plan for the remaining research work to be completed. It is evaluated according to a rubric distributed by the Graduate Student Progress committee.

The oral exam is a public presentation based on their written document (similar to a thesis defense presentation, but more as a discussion of what will be done and how and why), followed by private oral questioning by the committee.

The student is allowed two (2) total attempts to pass the comprehensive examination. If the comprehensive exam is failed on the first attempt, at least 6 calendar months must elapse before the second attempt at the examination. Failure to pass the comprehensive exam on the second attempt results in termination of graduate study and dismissal from the academic program. Students who are dismissed from the program due to a second failed attempt are ineligible to reapply to the same degree program.

### **2.4.3 Dissertation defense**

The objective of the dissertation defense is to examine the student's research accomplishments and his or her ability to communicate their research results in a professional manner at the level of an independent professional researcher. The dissertation defense is supervised by the student's Ph.D. committee chair and must be attended by the full supervisory committee.

The first part of the exam is held in a public meeting where the Ph.D. student gives an oral presentation describing and summarizing the dissertation project. This public presentation should not last more than one hour, including a question-and-answer period during which attendees may ask questions about the presentation. The public presentation is followed by a private meeting with the supervisory committee and student. The committee, the ECE department head, and the Graduate School must approve the dissertation before the Ph.D. degree can be conferred.

The dissertation defense is held upon completion of all course work and preparation of a dissertation that is deemed by the advisor as being ready for defense. The defense must be held within 5 years of the comprehensive exam and at before the Graduate School deadlines (typically

2 weeks before the end of the semester of graduation). The comprehensive examination and the dissertation defense cannot be held in the same semester.

## **2.5 Dissertation guidelines**

The Ph.D. dissertation is a detailed report of original research conducted by the graduate student with guidance from his or her advisor and supervisory committee. It must have significant scope, depth, and novelty, such that at least selected results can be published in one or more peer-reviewed archival journals. There is no mandatory number of publications required, but journal publications must result from a Ph.D. project.

All dissertations at Montana State University are submitted in electronic form, so the student can use color figures and even multimedia as appropriate. For details on format and submission requirements, the student is referred to the Graduate School (specific format requirements are at <http://www.montana.edu/etd/> but each student chooses a reference style following the standards of a journal in their field).

## **3 MSEE Program Requirements and Procedures**

### **3.1 M.S. in Electrical Engineering with Thesis (Plan A)**

The thesis-based Master of Science in Electrical Engineering (plan-A MSEE) is a research-oriented degree intended to provide the student advanced education that goes deeper than the undergraduate degree and experience working on a cutting-edge engineering research project. All plan-A M.S. students must conduct a research project that is reported in a written thesis and defended at the Comprehensive Oral Examination prior to graduation. Most plan-A M.S. students conduct their research with support from a research assistantship provided by faculty research funds.

#### **3.1.1 Supervisory Committee**

Each M.S. student is responsible for finding an appropriate research project and advisor. The advisor usually is the faculty member whose research grant provides RA funding. By the middle of their second semester in the graduate program, each student must choose their supervisory committee members, in consultation with their advisor who serves as the committee chair and file a *Program of Study* approved by all committee members. The M.S. supervisory committee has overall responsibility for guiding the student toward successful completion of the degree and for examining the student prior to graduation. Each committee member reads the thesis, attends the thesis defense and oral comprehensive exam, and votes to pass or fail the student in their M.S. program.

The M.S. supervisory committee consists of the chair (typically the advisor) and at least two (2) additional members chosen by the student and his or her committee chair. The committee chair must be a tenure-track faculty member in the ECE department at MSU-Bozeman. The other two members can be chosen from the tenure-track and adjunct faculty of the ECE department and allied departments or outside organizations, but the majority (half in the case of 4 members) of the committee must be from the ECE tenure-track faculty. A committee member from outside the MSU faculty must be approved by the Graduate School, following submission of a CV for the nominated committee member and a letter of recommendation by the Department Head.

#### **3.1.2 Program of Study**

To remain in good standing, the student must complete the *Program of Study* form and have it approved by the supervisory committee and the Graduate School before the end of their second semester in the graduate program. This form lists all courses to be taken by the student for their graduate degree. Students are encouraged to include courses in their program of study from appropriate fields outside of ECE, such as mathematics, statistics, physics, and computer science.

For a plan-A M.S. EE degree, the program of study must include:

- 10 credits of *Master's Thesis* (EELE 590)  
[Note: a student who has taken *Ph.D. Dissertation* (EELE 690) credits may use them in place of EELE 590 if earning a M.S. en route to Ph.D. or if converting from Ph.D. to M.S. status.]
- 20 credits of coursework
  - $\leq 10$  credits at 400 level and all other course credits at 5xx or 6xx level (ECE-unique exception provided by the Graduate School)

Further conditions on the distribution of course credits are as follows:

- All courses must be less than 6 years old at the time of graduation.
- $\leq 4$  credits *Independent Study* (EELE 592) for plan-A M.S. degree
- $\leq 10$  credits total of EELE 592 and graduate seminar courses (e.g., ENGR 650)
- $\leq 3$  credits pass/fail (not counting thesis)
- $\leq 6$  credits may be challenged
- No credits of 488, 489, 490, 492, 494, 498, 575, or 589 are allowed

### 3.1.3 Timeline

#### By middle of second semester

Assemble supervisory committee and file *Program of Study* form to the Graduate School for approval (file any necessary changes to the program of study before the end of the affected term).

#### As early as possible

Present a thesis proposal to the supervisory committee.

#### In graduation term

- Register for  $\geq 3$  credits.
- Submit *Application for Advanced Degree* to the Graduate School by September 20 for Fall, February 5 for Spring, or June 10 for Summer.
- Schedule *Comprehensive Oral Exam and Thesis Defense* sufficiently early that all committee-required thesis edits can be completed after the defense and by the Graduate School deadline, typically Dec. 1 for Fall, April 21 for Spring, and July 21 for Summer.
- Deliver completed thesis to supervisory committee at least 2 weeks before defense.
- Pass *Thesis Defense* and make thesis corrections or modifications required by committee by Graduate School deadlines referred to above.
- Submit electronic thesis, *Electronic Thesis/Dissertation Approval Form* signed by all committee members, and *Thesis/Dissertation/Professional Paper Report* signed by the ECE department head, to the Graduate School by Graduate School deadlines referred to above.

Note that several items must be completed by Graduate School deadlines that are approximately two weeks before the end of the graduation term, but there can be significant delays between completing each item. For example, it typically takes one week or longer after the thesis defense before the thesis can be submitted to the Graduate School; it also can take several days to obtain Graduate School approval. In other words, it is essentially impossible to meet graduation deadlines if the thesis is not being written at the start of the graduation semester or if the defense is held later than about three weeks before the end of the term.

### **3.1.4 MSEE Plan A Examinations**

Students in the MSEE program only have one major examination, the comprehensive examination and thesis defense (two names, one event). This is a culminating test of the student's learning and accomplishments. The written portion of this examination is the thesis itself, which must be approved in format and content (including proper grammar and writing style) by the committee. Because it is common for the committee to require thesis editing and modification following the defense, the student must schedule their thesis defense early enough in the graduation term to have sufficient time to make these changes and gain the approval of their committee before the Graduate School thesis submission deadline. As an approximate guideline, obtaining final committee and department approval of a successfully defended thesis often takes at least one week. The thesis should not be given to the committee members before the advisor has read, edited, and approved it for distribution. The advisor must grant approval for the student to schedule his or her thesis defense and may do so in consultation with the student's supervisory committee.

The oral comprehensive examination includes a public oral presentation by the student of their thesis project, followed by a closed-door period during which the committee members ask questions related to the thesis project and the student's academic background (including courses taken by the student and material expected to be known by a professional at this level in the field). The oral examination and thesis defense are supervised by the advisor. For the student to pass this examination, a majority of the committee must vote to pass. If a majority votes to fail, the student fails the examination. The examination can be repeated once, no sooner than two months after the failed attempt. A second failure results in suspension from the graduate program. If a thesis requires other than minor revisions that can be completed within the one-week deadline for reporting the outcome of the comprehensive examination and thesis defense, the student should be failed. If the oral comprehensive examination is deemed acceptable, the supervisory committee may choose to forego a second thesis defense presentation or oral examination and simply meet with the student to review the revised thesis.

### **3.1.5 Thesis Guidelines**

The M.S. thesis is a report of research performed by the student with guidance from their supervisory committee. The thesis topic is approved early in the student's degree program by the committee, and typically arises as part of the advisor's externally funded research program. The project must involve a significant effort by the student and must generate results that are of sufficient quality and significance to be reported in at least one national or international conference presentation or paper.

All theses at MSU are submitted in electronic form, so the student can use color figures and even multimedia as appropriate. For details on format and submission requirements, the student is referred to the Graduate School (specific format requirements are available online at <http://www.montana.edu/etd/> but each student chooses a reference style following the standards of a journal in their field). Each student must also submit an electronic copy of their thesis to the ECE department before graduating.

## 3.2 M.S. in Electrical Engineering with Professional Paper (Plan B)

A plan-B Master of Science in Electrical Engineering (plan-B MSEE) is a practice-oriented degree intended to provide the student advanced education that goes deeper and broader than the undergraduate degree and to provide experience working on a professional engineering project. All plan-B MSEE students must write a professional paper that is approved by their advisor and pass an oral comprehensive examination with their supervisory committee.

### 3.2.1 Supervisory Committee

Each plan-B M.S. student must find an appropriate project and advisor and, by the end of their second semester in the graduate program, choose their supervisory committee members (in consultation with their advisor who serves as the committee chair) and file a *Program of Study* form approved by all committee members. The M.S. supervisory committee has overall responsibility for guiding the student toward degree completion and for examining the student prior to graduation. The advisor reads and approves the professional paper, and each committee member attends the comprehensive oral examination and votes to pass or fail the student in their M.S. program.

The M.S. supervisory committee consists of the chair (typically the advisor) and at least two (2) additional members chosen by the student and his or her committee chair. The committee chair must be a tenure-track faculty member in the ECE department at MSU-Bozeman. The other two members can be chosen from the tenure-track and adjunct faculty of the ECE department and allied departments or outside organizations, but the majority (half in the case of 4 members) of the committee must be from the ECE tenure-track faculty. A committee member from outside the MSU faculty must be approved by the Graduate School, following submission of a CV for the nominated committee member and a letter of recommendation by the Department Head.

### 3.2.2 Program of Study

To remain in good standing, the student must complete the *Program of Study* form and have it approved by the supervisory committee and the Graduate School before the end of their second semester. This form lists all courses to be taken by the student for their graduate degree. Students are encouraged to include relevant courses in their program of study from non-ECE departments.

For a plan-B M.S. EE degree, the program of study must include:

- 3 or 6 credits of *Professional Paper/Project*, EELE 575 (see Section 4.5 for discussion of the difference between a 3-credit and 6-credit professional paper)
- 24 or 27 credits of coursework to reach a total of 30 credits including professional paper
  - $\leq 10$  credits at the 4xx level with all other course credits at the 5xx-6xx level (ECE-unique exception provided by the Graduate School)

Further conditions on the distribution of course credits are as follows:

- All courses must be less than 6 years at the time of graduation.
- $\leq 6$  credits *Independent Study* (EELE 592)
- $\leq 10$  credits EELE 592 and seminar courses
- $\leq 3$  credits pass/fail
- $\leq 6$  credits may be challenged
- No credits of 488, 489, 490, 492, 494, 498, 575, or 589 are allowed

### 3.2.3 Timeline

#### By end of second semester

Assemble supervisory committee and file *Program of Study* form to the Graduate School for approval (file any necessary changes to the program of study before the end of the affected term).

#### As early as possible

Present professional paper proposal to the advisor (and committee if desired by the advisor).

#### In graduation term

- Register for  $\geq 3$  credits.
- Submit *Application for Advanced Degree* to the Graduate School by September 20 for Fall, February 5 for Spring, or June 10 for Summer.
- Schedule *Comprehensive Oral Exam* to occur by the Graduate School deadline, typically Dec. 1 for Fall, April 21 for Spring, and July 21 for Summer.
- Deliver advisor-approved professional paper to supervisory committee at least 2 weeks before defense.
- Pass *Comprehensive Oral Exam* by Graduate School deadline, typically Dec. 1 for Fall, April 21 for Spring, and July 21 for summer.
- If the professional paper is being submitted for posting on ScholarWorks (in MSU thesis format), submit electronic professional paper, *Electronic Thesis/Dissertation Approval Form* signed by all committee members, and *Thesis/Dissertation/Professional Paper Report* signed by the ECE department head, to the Graduate School by Graduate School deadline.

### 3.2.4 MSEE Plan B Examination

The plan-B M.S. EE degree requires a *comprehensive oral examination* as the culminating test of the student's learning and accomplishments. In contrast with the plan-A examination that focuses heavily on the thesis defense, the plan-B examination addresses content of the professional paper and a broader range of content from courses taken by the student and knowledge that should be held by a beginning professional in the field. The supervisory committee can offer suggestions for the professional paper, but the letter grade for the paper is assigned solely by the advisor.

The comprehensive oral examination is a closed meeting during which the supervisory committee members ask questions related to the student's professional paper and coursework. The examination proceedings are supervised by the advisor. For the student to pass, a majority of the committee must vote to pass; if a majority of the committee votes to fail, the student fails the examination. The examination can be repeated once, no sooner than two months after the failed attempt. A second failure results in suspension from the ECE graduate program.

### 3.2.5 Professional Paper Guidelines

The MSEE program plan-B professional paper is a report of work performed by the student at the level of an early-career professional, practicing engineer, with guidance from the advisor. The paper can report on any topic approved by the advisor, but usually covers some focused aspect of a research, design, or educational project. The project must involve a significant effort by the student but is not as comprehensive as a thesis and does not need to be original research published in the archival literature. It is desirable that a plan-B M.S. project contribute to a conference (or

journal) paper.

A 3-credit professional paper summarizes work that is comparable to a single 3-credit graduate course. A 6-credit professional paper reports a more complete study that extended for a longer time and into a deeper or broader range of work. It is, however, still a less complete study than would be expected for a 10-credit M.S. thesis.

The professional paper must be approved in format and content (including proper grammar and writing style) by the advisor. Students must submit their draft paper early enough to leave time for editing before the end of the term. Plan-B professional papers normally are submitted in electronic form only to the ECE department, so the student and advisor are free to choose a format that is appropriate in the subfield represented by the work (often the format of a journal in the field), without a need to follow the Graduate School formatting guidelines. However, in some cases, the advisor may choose to have a student submit their professional paper to the Graduate School for distribution via ScholarWorks. In this case, the paper must be formatted in accordance with the thesis requirements published by the Graduate School and must be submitted by the Graduate School deadline for the graduation semester.

## 4 MSOP Program Requirements and Procedures

The Master of Science in Optics and Photonics (MSOP) program leads to a research-oriented degree that can be completed with either a thesis (Plan-A) or professional paper (Plan-B) option. Students can be admitted to this degree through the Departments of Electrical and Computer Engineering, Physics, and Chemistry and Biochemistry. Regardless of admitting department, all students in the MSOP program fulfill the same core requirements (but their elective courses may be different).

### 4.1 Supervisory Committee

Each student in the MSOP program must find an appropriate project and advisor and, by the end of their second semester in the graduate program, choose their supervisory committee members (in consultation with their advisor who serves as the committee chair) and file a *Program of Study* form approved by all committee members. The supervisory committee has overall responsibility for guiding the student toward degree completion and examining the student prior to graduation. Each committee member reads and approves the thesis for a plan-A degree but only the advisor assigns a grade for the plan-B professional paper credits (OPTI 575). All committee members attend the comprehensive oral examination and votes to pass or fail the student in their MSOP degree program.

The MSOP supervisory committee consists of the chair (typically the advisor) and at least two (2) additional members chosen by the student and his or her committee chair. The committee chair must be a tenure-track faculty member in the student's admitting department. The other two members can be chosen from the tenure-track and adjunct faculty of the MSOP participating departments. For a more diverse student experience, it is recommended that the MSOP supervisory committee include faculty from at least two participating departments. A committee member from outside the MSU faculty must be approved by the Graduate School, following submission of a CV for the nominated committee member and a letter of recommendation by the Department Head.

### 4.2 Program of Study

To remain in good standing, the student must submit the *Program of Study* form and have it approved by the supervisory committee and the Graduate School before the end of the second semester of graduate enrollment. This form lists all courses to be taken by the student for their graduate degree.

For a M.S. in Optics and Photonics degree, the program of study must include:

- One of PHSX 427 (Advanced Optics) or EELE 482 (Electro-Optical Systems).
- One of PHSX 437 (Laser Applications) or EELE 584 (Laser Engineering)
- One specialty course from the following list:
  - EELE 581 Fourier Optics & Imaging Theory
  - EELE 582 Optical Design
  - PHSX 531 Nonlinear Optics & Spectroscopy
  - CHMY 527 Optical Spectroscopy
  - CHMY 560 Symmetry, Orbitals, and Spectroscopy
- 6 credits of optics electives chosen from the following:
  - EELE 432 Applied Electromagnetics
  - EELE 482 Electro-Optical Systems

- EELE 584 Laser Engineering
- EELE 538 Advanced Topics in EM & Optics
- EELE 581 Fourier Optics & Imaging Theory
- EELE 582 Optical Design
- EELE 583 Remote Sensing Systems
- PHSX 427 Advanced Optics
- PHSX 437 Laser Applications
- PHSX 507 Quantum Mechanics II
- PHSX 515 Advanced Topics in Physics<sup>1</sup>
- PHSX 520 Electromagnetic Theory II
- PHSX 531 Nonlinear Optics & Spectroscopy
- CHMY 421 Advanced Instrument Analysis
- CHMY 527 Optical Spectroscopy
- CHMY 557 Quantum Chemistry
- CHMY 560 Symmetry, Orbitals, and Spectroscopy
- CHMY 564 Advanced Quantum Chemistry
- EELE, PHSX, CHMY 591 Special Topics<sup>1</sup>
- EELE, PHSX, CHMY 592 Independent Study<sup>1</sup>
- OPTI 594 Optics Seminar<sup>2</sup>
- 5 credits of technical electives at 4xx level or above (ECE, Physics, Math, Stat, Chemistry and Biochemistry, Business, Biology, CS, etc., as appropriate to student interests).
- 10 credits specific to plan-A or plan-B option:
  - Plan-A: 10 credits of Master's Thesis (OPTI, EELE, PHSX, or CHMY 590)
  - Plan-B: 3 credits Professional Paper (OPTI 575) and 7 additional elective credits.

Further conditions on the distribution of course credits are as follows:

- All courses must be less than 6 years at the time of graduation.
- At least 20 credits must be at the 5xx level

### 4.3 Timeline

#### By end of second semester

Assemble supervisory committee and file *Program of Study* form to the Graduate School for approval (file any necessary changes to program of study before the end of the affected term).

#### As early as possible

Present thesis or professional paper proposal to the advisor and committee.

#### In graduation term

- Register for  $\geq 3$  credits.
- Submit *Application for Advanced Degree* to the Graduate School by September 20 for Fall, February 5 for Spring, or June 10 for Summer.
- Schedule *Comprehensive Oral Exam and Thesis Defense* to occur early enough to allow committee-required thesis or professional paper modifications to be complete by the Graduate School deadline, typically Dec. 1 for Fall, April 21 for Spring, and July 21 for Summer.
- Deliver advisor-approved professional paper to supervisory committee at least 2 weeks before defense.

- Pass *Comprehensive Oral Exam and Thesis Defense* by Graduate School deadline, typically Dec. 1 for Fall, April 21 for Spring, and July 21 for summer.
- Submit committee-approved electronic thesis (or professional paper if written in thesis format), *Electronic Thesis/Dissertation Approval Form* signed by all committee members, and *Thesis/Dissertation/Professional Paper Report* signed by the admitting department head, to the Graduate School by Graduate School deadline.

#### **4.4 M.S. in Optics and Photonics Comprehensive Examination**

All Optics and Photonics master's degree students are required to defend their thesis or professional paper in a public oral presentation for their comprehensive exam. The thesis or paper constitutes the written comprehensive exam and the questioning by the supervisory committee following the student's presentation constitutes the oral comprehensive examination. Following the public presentation, the Comprehensive oral examination continues in a closed meeting during which the supervisory committee members ask questions related to the student's professional paper and coursework. The examination proceedings are supervised by the advisor. A majority vote is required for the student to pass; if a majority votes to fail, the student fails the examination. The examination can be repeated once, no sooner than two months after the failed attempt. A second failure results in suspension from the MSU graduate program.

#### **4.5 M.S. in Optics and Photonics with Thesis (Plan-A)**

The M.S. in Optics and Photonics plan-A thesis is a report of research performed by the student with guidance from their supervisory committee. The thesis topic is approved early in the student's degree program by the committee, and typically arises as part of the advisor's externally funded research program. The project must involve a significant effort by the student and must generate results that are of sufficient quality and significance to be reported in at least one national or international conference presentation or paper.

All theses at MSU are submitted in electronic form, so the student can use color figures and even multimedia as appropriate. Students are referred to <http://www.montana.edu/etd> for details on format and submission requirements (using a reference style conforming to a journal in their field).

#### **4.6 M.S. in Optics and Photonics with Professional Paper (Plan-B)**

The M.S. in Optics and Photonics plan-B professional paper is a report of work performed by the student at the level of an early-career professional, practicing engineer, with guidance from the advisor. The paper can report on any topic approved by the advisor, but usually covers some focused aspect of a research, design, or educational project. The project must involve a significant effort by the student but is not as comprehensive as a thesis and does not need to be original research published in the archival literature. It is desirable that a plan-B M.S. project contribute to a conference (or journal) paper. A 3-credit professional paper summarizes work that is comparable to a single 3-credit graduate course.

The professional paper must be approved in format and content (including proper grammar and writing style) by the advisor. Students must submit their draft paper early enough for editing before the end of the term. Professional papers are not required to be submitted in electronic form to the Graduate School, so the student and advisor are free to choose a format that is appropriate in the student's subfield (often the format of a journal in the field). However, the advisor may choose to

have a student submit their professional paper to the Graduate School for distribution via ScholarWorks. In this case, the paper must be formatted in accordance with the thesis requirements published by the Graduate School and must be submitted by the Graduate School deadline for the graduation semester.

## 5 MENG Program Requirements and Procedures

A Master of Engineering (M.Eng.) degree in Electrical Engineering is a practice-oriented degree intended to provide the student advanced education that goes deeper and broader than the undergraduate degree, but without a research component. For example, this degree is particularly relevant to engineers employed in industry who desire further training through advanced courses. MENG students are not required to take either a qualifying or comprehensive exam, but instead satisfy degree requirements through coursework exclusively. Students in the MENG program are generally not eligible for departmental financial support.

### 5.1 Supervisory Committee

Each student in the MENG program is advised by the ECE Department Graduate Coordinator. There is no supervisory committee.

### 5.2 Program of Study

The *Program of Study* form must be completed by the student and approved by the ECE Graduate Coordinator before the end of the student's second semester in the program. Failure to meet this deadline constitutes lack of progress toward the degree and is grounds for probation, suspension of financial support, and possibly dismissal from the graduate program. This form lists all courses to be taken by the student for their graduate degree (except any additional courses required by the advisor to correct deficiencies and weaknesses). Students are encouraged to include courses in their program of study from appropriate departments outside of ECE, such as mathematics, statistics, physics, and computer science.

An M.Eng. degree program of study must include:

- 30 credits of courses selected either from the M.Eng. degree approved course list or by petition.
  - $\geq 18$  course credits at 5xx-6xx level.
  - $\leq 12$  credits at 4xx level.

Further conditions on the distribution of course credits are as follows:

- $\leq 9$  credits can be reserved for graduate credit during an undergraduate program (these credits do not count toward the undergraduate degree).
- $\leq 9$  credits of non-ECE classes are allowed.
- All courses must be less than 6 years old at the time of graduation.
- $\leq 6$  credits *Independent Study* (EELE 592).
- $\leq 10$  credits total EELE 592 and seminar courses.
- $\leq 3$  credits pass/fail.
- $\leq 6$  credits may be challenged.
- No credits of 488, 489, 490, 492, 494, 498, 575, or 589 are allowed.

### 5.3 Timeline

#### On admission

Meet with Graduate Coordinator and file *Program of Study* form to the Graduate School for approval (file any necessary changes to program of study before the end of the affected term).

In graduation term

- Register for  $\geq 3$  credits.
- Submit *Application for Advanced Degree* to the Graduate School by the Graduate School deadline, typically September 20 for fall, February 5 for spring, or June 10 for summer.

Note: There are no qualifying or comprehensive exams required for the M. Eng. Degree, which is earned exclusively by satisfying the requisite coursework with acceptable grades.

## 6 Tenure-Track Faculty

### **James Becker, Professor**

*Ph.D. Electrical Engineering, University of Michigan*

*M.S. Electrical Engineering, Colorado State University*

*B.S. Ceramic Engineering, University of Illinois, Urbana-Champaign*

Research interests: Applied electromagnetics, micromachining, pedagogical research.

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### **David Dickensheets, Professor**

*Ph.D. Electrical Engineering, Stanford University*

*M.S. Electrical Engineering, University of Washington*

*B.S. Electrical Engineering, University of Colorado*

Research interests: MOEMS, active and adaptive optics, tissue spectroscopy.

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### **Hongwei Gao, Associate Professor**

*Ph.D. Electrical Engineering, Texas A&M University*

*M.S. Electrical Engineering, Tsinghua University*

*B.S. Electrical Engineering, Tsinghua University*

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### **Todd Kaiser, Professor & Department Head**

*Ph.D. Electrical Engineering, Georgia Institute of Technology*

*M.S. Physics, Oregon State University*

*B.S. Physics, Montana State University*

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### **Anja Kunze, Assistant Professor**

*Ph.D. Microsystems & Microelectronics, Ecole Polytechnique Federale de Lausanne*

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### **Brock LaMeres, Professor**

*Ph.D. Electrical Engineering, University of Colorado – Boulder*

*M.S. Electrical Engineering, University of Colorado – Colorado Springs*

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### **Robert Maher, Professor**

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**Wataru Nakagawa, Associate Professor**

*Ph.D. Electrical and Computer Engineering, University of California-San Diego*  
*M.S. Electrical and Computer Engineering, University of California-San Diego*  
*B.S. Physics, Stanford University*  
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**Kevin Repasky, Professor**

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**Ioannis (John) Roudas, Professor**

*Ph.D. Optical Communications, Telecom ParisTech*  
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Research interests: Modeling and simulation of coherent optical communications systems, Digital signal processing algorithms for optical transceivers, Data center optical interconnects, Transparent displays  
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**Joseph Shaw, Professor and Director of the Optical Technology Center**

*Ph.D. Optical Sciences, University of Arizona*  
*M.S. Optical Sciences, University of Arizona*  
*M.S. Electrical Engineering, University of Utah*  
*B.S. Electrical Engineering, University of Alaska*  
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**Steven Shaw, Professor**

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*E.E., Massachusetts Institute of Technology*  
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**Ross Snider, Associate Professor**

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*M.S. Electrical Engineering, Michigan State University*  
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Research interests: Digital signal processing, field programmable gate arrays (FPGA).

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**Bradley Whitaker, Assistant Professor**

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**Ying Zhang, Assistant Professor**

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*B.S. Electrical Engineering, Shandong University*

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